Clay Pipe News

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SUBSOIL DRAINS

Water in the soil is the cause of inestimable damage to surface structures. It softens the subgrade, robbing it of its ability to support heavy loads. In cold climates this water freezes and causes "heaving." Recognition of these facts has resulted in a new science—subsoil drainage. Today it is good engineering practice to use a system of clay subdrains to protect the subbases of airport runways, landing fields, factories, homes, housing projects, bridge approaches, highways, railways, retaining walls and other structures that require firm, all-weather bases.

Above left: Clay subdrains being laid to protect a new highway. Above right: clay subdrains being installed in a wet spot on a mainline railway track. Below left: Large clay pipe drain being laid to eliminate an unsightly and dangerous ditch. Below right: Perforated clay subdrains being installed under a superhighway before surfacing.

WHAT IS SUBSOIL DRAINAGE?

The purpose of subsoil drainage is to remove from the ground all water which imperils the stability of structures built on or near the surface.

The importance of subdrainage cannot be over-emphasized. Where highways, railways, airport runways, retaining walls, buildings and other structures are built upon well-drained ground, repair costs due to settling, frost heaves, slides and loss of foundation support are minimized.

The highway surfacing seen to the right in the above photo is literally floating on a layer of unstable, water-soaked earth.

Although this is an elementary fact, too little attention has been given to the conditions under which subgrades maintain their stability. In practically all cases, a dry subgrade is a firm subgrade. There are obvious exceptions to this rule, but little scientific knowledge is needed to tell whether or not a dry soil has the necessary stability to support a given load.

On the other hand, there are very few soils that retain their stability when wet. A structure or surfacing built on a foundation filled with water is literally floating and in time parts of it will sink or shift.

Good surface draining does much to quickly carry away surface water that might otherwise percolate into the subsoil. But surface drainage in itself is not sufficient. Despite the most scientific surface drainage, water gets into the subsoil. This water must be removed. There is no other way to permanently stabilize the soil.

There is nothing difficult or profound about subgrade drainage. Fig. 1 shows the general idea.

Water is usually trapped by an impervious stratum in the soil. Such water has no way to escape except by capillary action and evaporation. If it is trapped near the surface, it imperils the permanence and stability of any structure built on top of the earth immediately over it. When clay pipe subdrains are properly installed, this trapped water is drained off.

The cost of subdrainage is small compared with the cost of the structures being stabilized. A few feet of clay pipe properly installed is a small price to pay for firm, trouble-free foundations . . . for better highways, railways, airport runways and landing fields . . . for all-weather parks and playgrounds, athletic fields and golf courses . . . for firmer foundations for all types of structures.

Agricultural subdrainage also pays big dividends to the farmer. It not only increases the production of the land but lets the farmer get on it earlier in the spring and sooner after rainfalls. Under new WPB rulings farmers do not need permission to buy and install clay subdrains under 12 inches in diameter.

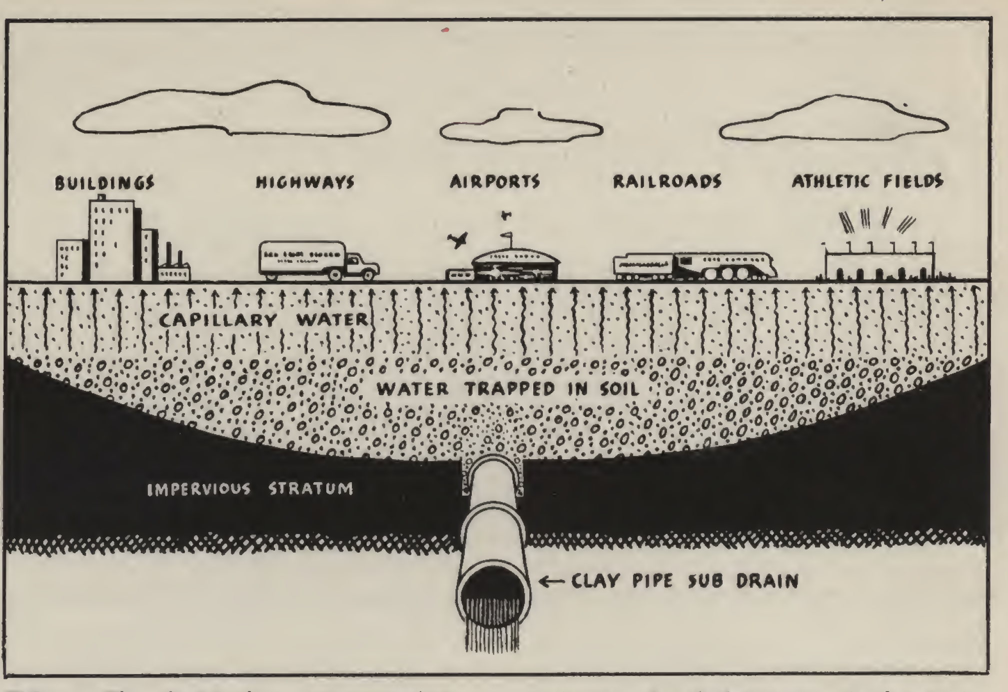


FIG. 1—This sketch shows in general the principle of subsoil drainage. A dense, impervious layer in the soil traps percolating water, forming a layer of water-soaked earth which lacks the stability to support buildings, highways, railways, airport runways, and other heavy or load-bearing structures. A clay pipe subdrain laid below the trapped water drains it off and stabilizes the earth.

FACTORS WHICH AFFECT DRAINAGE

Subsoil drainage must be carefully planned if it is to perform its work efficiently. Some subsoil drainage installations require extensive research before a trench can be opened or a length of pipe laid. Large airports are of this type. Here, and in similar construction, it is almost imperative to have topographical maps, layout maps, maps showing drainage subdivisions, profiles, data on outlet conditions, temperature data, snow data, rainfall-frequency data, soil profiles and data on infiltration capacities affecting the design of storm drains. On the other hand, a subdrain laid to protect the foundation of a bungalow requires little of this technical information.

But whether the subdrainage is to protect a highway, railroad, airport, athletic field or the foundation of some structure, there are certain basic factors which will influence the final installation. These are:

1. THE SLOPE OF THE SURFACE

The slope of the surface and character of the soil will determine the run-off of the surface waters and the location of catch basins, trenches, etc. Trenches should be run at right angles to the direction of flow. Methods of computing the run-off volume to be expected from various areas and soils will be found on pages 4 and 5.

2. THE TYPE AND STRATIFICATION OF THE SOIL

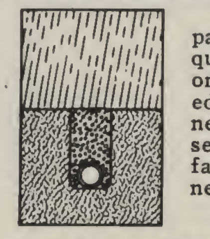
Soil profiles will provide an accurate knowledge of soil conditions and permeability. Such profiles should take into consideration the types of materials used for filling and the methods used to compact them; also the characteristics of the soils exposed by grading.

"The soil texture, consistency and composition which may be measured by tests, intimately affect percolation and permeability and, in turn, the drainage problem. The completed soil investigation with interpretation of results should be available to the designer of the drainage system as it is the only adequate and reliable source of information of the most important factors in drainage design. Particular significance should be attached to the location of any impervious, or relatively impervious, strata underlying the surface soil. The location of such impervious layers will have an important bearing upon the height of the water table and capillary rise and will influence the selection of drainage methods."[1]

Although the above quotation was written for those designing airport drainage systems, the same holds true for other major installations.

In brief, there are five major soil profiles, each with its own drainage problem:

a. Uniform and Pervious Soils



These permit water to pass through them fairly quickly and require little or no subdrainage, provided there is no water table near the surface. Storm sewers to carry away surface waters are all that is necessary.

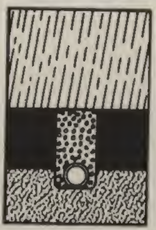
b. Uniform and Impervious Soils

Here the soil is of a type that does not readily permit water to pass through it. Rainfall lies on the surface until the earth soaks part of it up and the rest evaporates. This type of soil necessitates trenches at low points backfilled with a pervious material with subdrains properly laid at the bottom.

c. Soils Pervious Above and Impervious Below

This condition permits water to pass through the top layers and collect on the dense stratum where it forms a dense layer of unstable, water-saturated soil. Such water must be removed by a system of subsoil drainage pipes laid a few inches below the impervious stratum.

d. Soils Impervious Above and Pervious Below



To carry away waters which collect on top of the impervious layer trenches much be dug through the impervious layer to the coarser material underneath. Subdrains should be laid under the top layer to catch and carry away the percolating water.

e. Irregular Strata of Pervious and Impervious Soils

Usually, under this condition, water pockets form between the strata. All such pockets must be drained with a system of subsoil drains.

3. GRAVITATIONAL AND CAPILLARY WATER IN THE SOIL

As part of the profile survey, borings should be made to determine whether or not a water table is close enough to the surface to peril the stability of the subgrade or contribute to frost heaves. Impervious layers in the soil often trap gravitational waters and form layers of water-soaked earth which can do enormous harm. It should be remembered that the water table is not necessarily level, and that the fall of a few inches of rain may raise it several feet.

From the water table water rises in the soil by capillary action. The height to which it will rise depends upon the type of soil. It is this capillary water in the soil that causes frost heaves. Frost penetrating the surface from above freezes the capillary water near the surface, but does not go deep enough to stop all capillary motion. Consequently, more water rises and feeds the original ice crystals, causing them to expand. Finally the time comes when the upward thrust of the ice mass erupts the surface and does considerable damage.

Capillary water cannot be drained from the soil; it can be controlled only by lowering the water table. Therefore, the drainage system should be designed to keep water tables below the levels where they can cause this trouble.

4. RAINFALL-INTENSITY AND FREQUENCY

Before an adequate drainage system can be designed, a careful study should be made of rainfall and snowfall in the territory. This will decide the maximum volume of storm water to be expected under normal conditions. With such data at hand adequate subdrains can be designed.

The following information pertaining to airport drainage is equally applicable to other kinds of subsoil drainage.

"For most sections of the country, use of the ten-year, one-hour maximum rainfall curves represent conservative drainage design practice and is therefore recommended. While many large cities design drainage for golf courses and playgrounds on a basis of a five-year maximum, for more important areas where uninterrupted use is important, the ten-year maximum is widely used for current practice. Main trunk line sewers are frequently designed on a basis of 20 to 30 year maximum. The adoption of the ten-year period in airport drainage design appears to insure the safety of normal operations and to afford the best compromise between accomplishing the immediate removal of all water and proper consideration of cost factors.

"The season of occurrence of the precipitation is another important factor which must be considered. In northern latitudes considerable precipitation may accumulate on the ground as snow, and a large portion of this may suddenly be carried into the drainage system as the result of warm rains or high temperatures.

"Over the plains area of the Northwest the winter precipitation is relatively light, averaging only about 1 inch per month, but temperatures are lower so that considerable snow may accumulate. In this region the probabilities of high surface flow or run-off are less for other sections, however, because the temperature rises rapidly in the spring, causing the melting and removal of the moderate snowfall before heavy spring rains set in.

"From the standpoint of drainage as employed under conditions typical of airport construction, that portion of the precipitation which percolates into the ground as the result of the permeability of the soil is of primary importance. Evaporation and transpiration losses may be ignored in the computation of surface run-off from an area as restricted in size as the average airport without seriously affecting design. The peak loads which the drainage system will have to handle will occur during and directly after periods of heavy precipitation, at which time the factor of evaporation and transpiration will be almost negligible. . . ."[2]

As stated above, the precipitation that percolates into the soil is of primary importance. What Professor Eno[3] says about this in connection with highway drainage also applies to other kinds of subdrainage:

"The run-off will form the large volume for which he (the Highway Engineer) must design, but he must not fail to consider the question of percolating water, for storm follows storm at irregular but often very close intervals, so that a maximum of seepage from one storm may be occurring exactly at the same time the maximum run-off from a succeeding storm is just arriving. The soil forms a reservoir, holding much percolating water, for, while storm water usually runs off over the surface rather rapidly, percolating water moves through the earth very slowly.

"The more intense the rainfall, the larger will be the percentage of rainfall that runs off over the surface, while the less intense the rainfall, the greater will be the percentage entering the earth as percolating water."

1 and 2. Airport Design Information, Civil Aeronautics authority, May, 1940.

3 F. H. Eno, Research Professor of Highway Engineering at the Ohio State University, in his report, SOME EFFECTS OF SOIL, WATER AND CLIMATE UPON THE CONSTRUCTION, LIFE AND MAINTENANCE OF HIGHWAYS, Bulletin No. 85, published by the Engineering Experiment Station, College of Engineering, Ohio State University.

THEORY AND PRACTICE OF SUBSOIL DRAINAGE

Water gets into subsoil in many ways. Much of it soaks in through unsurfaced areas. On highways and airports, some may seep in through expansion joints in the pavement or soak through pervious surfacing materials. Some may flow in from higher ground adjacent to the site over impervious layers in the soil. Some may come from springs.

If the soil condition were uniformly porous, surface water would percolate to a depth where it could do no harm, but under ordinary conditions the downward movement of such water is halted by dense or impervious strata in the soil. A layer of soft, water-soaked earth is thus formed on top of the strata and this is what causes most subgrade instability.

To remove this water the engineer lays a drainage line of regular or perforated vitrified clay bell and spigot pipe with open joints below the water table. The trench is then backfilled with a porous material to quicken drainage into the pipe. The installation of drains is described in greater detail in the next section.

When the impervious strata in the soil have a slope the water flows down them and collects in pockets. The flow is very slow but definite. The depth and direction of the flow can be determined by test borings and a complete topographical survey of the site and contiguous territory. To stop the movement of such water, trenches are dug at right angles to the direction of flow. The pipe is laid and backfilled as for other subsoil drainage installations.

TIME INCREASES EFFICIENCY

New pipes begin their work by draining only the underground waters immediately adjacent to them. Then gradually they expand their drainage area, as nature provides a system of waterways through the pores or open spaces in the soil. These are somewhat similar to the veins in the human body. As time passes, subsoil drains become more and more effective, until they reach their maximum efficiency.

It will be noticed in Figure 3 that an installation of this type does not lower the level of the entire water table, but simply makes a hole in it. The closer the spacing of the subdrains, the lower the water table will become. This is well illustrated in Figure 4. The type of soil in which the drains are laid will also influence their effectiveness. Table I will be of help in determining the spacing of subdrains for maximum efficiency.

DRAINAGE LAYOUTS

The layout for a system of subdrains varies with the problem in hand.

A complete drainage system has a threefold function:

1. To remove both surface and subsoil water from areas outside the site of construction where these affect the stability of the site.
2. To remove the subsoil water on the site of construction where it imperils the stability of the soil.
3. To remove surface water from the site, especially from large surfaced areas, roofs and so forth, before it has a chance to get into the subsoil.

In many cases all three of these functions are performed by the same system of drains. In other cases the first two functions are handled by one system and the third by a separate installation.

Illustrated in Figure 2 are four common drainage-layout systems commonly used to drain large areas.

1. The herringbone system
2. The natural system
3. The parallel system
4. The gridiron system

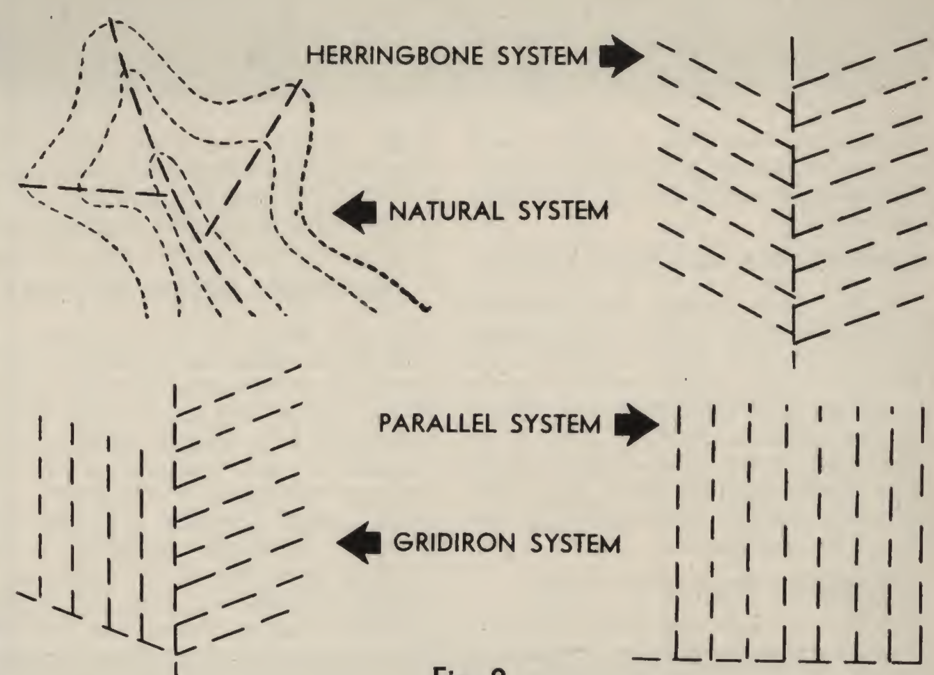


Fig. 2

Trunk drain lines are laid at strategic topographical locations. These collect the flow from lateral drains and catch basins and carry it to the point of discharge. Catch basins are placed at the lowest points in the grade. The location and depth of the mains and laterals will depend upon the layout of the airport, park or other site of construction, the load to be supported by the drain, the area to be drained, the depth of the water table, the location and the outlet, the elevation of the site and other factors.

COMBINATION DRAINS

Where one system must give both surface and subsurface drainage, the trench is usually completely backfilled with a porous material. Surface waters find their way into the pipes by percolating through the coarse backfill or through catch basins of extra coarse material. In some instances where the volume of surface water is great, such as that which runs off large surfaced areas, regular grated sewer inlets are used.

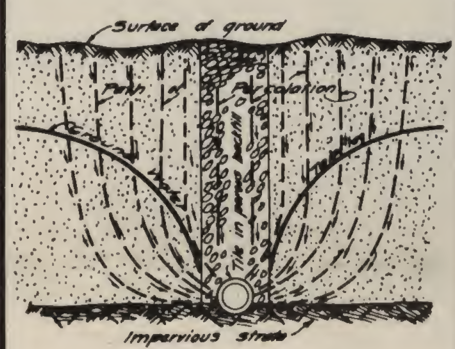


Fig. 3

PATH OF GROUND WATER TO CLAY SUBDRAIN

For Ideal Conditions

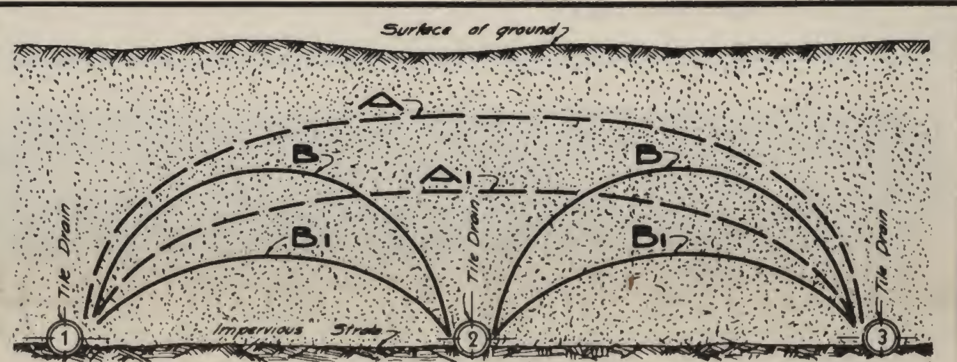


Fig. 4 CROSS SECTION OF DRAIN LINES SHOWING HOW CLOSER SPACING OF LINES LOWERS THE WATER TABLE.

NOTE: For ideal soil conditions the curves above represent approximately the position of the ground water surfaces, showing they are lowered by closer spacing of the drain lines.

Curve A shows the water table for two drain lines 1 and 3 immediately after a rain. In a short time this water table is lowered to A1 by the functioning of the drain lines.

Curves B and B1 represent water tables for three lines of drains for the same time interval as for curves A and A1.

The area between A1 and B1 shows the increase in the space drained by the addition of one line of clay pipe.

INSTALLATION OF SUBDRAINS

The function of a subdrain is to collect and remove subsoil water. To accomplish this vitrified clay pipe of sufficient size is laid with open joints in a trench which is backfilled with a coarse, pervious material. Some engineers prefer to use perforated clay pipe for this purpose.

TRENCHES

Trenches should have a width equal to the outside diameter of the pipe plus a minimum of six inches. This permits the coarse backfill to completely surround the pipe and thus prevents clogging.

Where the floor of the trench is soft, muddy or uneven, the excavation should be dug three to six inches below grade and then brought up to grade again with a pervious backfill. This allows water to enter all sides of the pipe and at the same time stabilizes the pipe foundation.

The depth of the trench will depend upon the location of the outlet, the elevations of the site, the depth of the water table or impervious substrata, the maximum load that the pipe must support, and the amount of money that can be spent on pervious material for backfilling. As shown in Figure 4 the deeper and closer together the drains are, the more nearly complete the drainage will be. Table I will be helpful in computing practical depth and spacing of drains.

LAYING THE PIPE

Common practice in drainage installation is to start laying the pipe at the outlet and to work up grade. The spigot end of the pipe always points in the direction of flow. To protect the joints from clogging until all silt has been washed down, burlap or bituminous-treated roofing is laid over the joints. Recesses should be dug in the floor of the trench for the bells and the lower 90 degree arc of the barrel of the pipe so that all weight is supported evenly by the barrel. See page 4 for suggestions on how to get maximum strength from clay pipe.

BACKFILL

The backfill for subdrains and interceptor drains may be crushed rock, crushed slag, gravel, oyster shells, or any other hard, durable material which will permit the quick passage of water. In installations where subdrains must also carry off surface water, the porous backfill is carried to the surface. Where this isn't desired, the backfill in the top portion of the trench is of natural earth or some impervious material.

TABLE I—SPACING AND DEPTH OF SUBDRAINS IN SOILS OF VARIOUS COMPOSITIONS

<table>
<tr><th>TYPE OF SOIL</th><th>FINE GRAVEL AND SAND</th><th>SILT</th><th>CLAY</th><th>RECOMMENDED DEPTH OF TRENCH IN FEET</th><th>RECOMMENDED DISTANCE BETWEEN DRAINS, IN FEET</th></tr>
<tr><td rowspan="2">Sand</td><td rowspan="2">More than 20%</td><td>0–15%</td><td>0–10%</td><td rowspan="2">5–6</td><td rowspan="2">150–300</td></tr>
<tr><td colspan="2">Less than 20%</td></tr>
<tr><td rowspan="2">Sandy Loam</td><td rowspan="2">More than 20%</td><td>10–35%</td><td>5–15%</td><td rowspan="2">3½–4</td><td rowspan="2">100–125</td></tr>
<tr><td colspan="2">More than 20% and less than 50%</td></tr>
<tr><td rowspan="2">Fine Sandy Loam</td><td rowspan="2">Less than 20%</td><td>10–35%</td><td>5–15%</td><td rowspan="2">3½</td><td rowspan="2">100–125</td></tr>
<tr><td colspan="2">More than 20% and less than 50%</td></tr>
<tr><td rowspan="2">Loam</td><td rowspan="2"></td><td>0–55%</td><td>15–25%</td><td rowspan="2">4</td><td rowspan="2">50–100</td></tr>
<tr><td colspan="2">More than 50%</td></tr>
<tr><td rowspan="2">Clay Loam</td><td rowspan="2"></td><td>25–55%</td><td>25–35%</td><td rowspan="2">3–4</td><td rowspan="2">35–60</td></tr>
<tr><td colspan="2">More than 50%</td></tr>
<tr><td rowspan="2">Clay</td><td rowspan="2"></td><td></td><td>35–100%</td><td rowspan="2">3–4</td><td rowspan="2">25–50</td></tr>
<tr><td colspan="2">More than 60%</td></tr>
</table>

PHYSICAL COMPOSITION OF SOILS FROM IOWA STATE COLLEGE ENGINEERING EXPERIMENT STATION BULLETIN No. 50
SPACING OF DRAINS FROM UNIVERSITY OF MINNESOTA TECHNICAL BULLETIN No. 101

HOW TO GET MAXIMUM STRENGTH FROM CLAY PIPE

By giving the pipe a better than average foundation and backfilling, its supporting strength can be increased considerably.

IMPERMISSIBLE METHOD OF LAYING

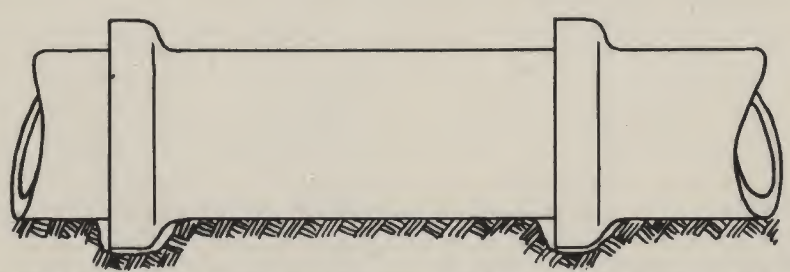
When a pipe is laid on a flat-bottomed square-cut ditch with excavations for the bells only (see figure 1 in Table II to the right) and the space around the pipe backfilled with coarse material without tamping, only 75 to 80 per cent of the supporting strength of the pipe is utilized. Because of this fact, this method of pipe laying is considered impermissible.

ORDINARY METHOD OF LAYING

When the floor of the trench is shaped to receive the lower quadrant of the pipe and bells (as shown in figure 2 in the table to the right) and the space around the pipe is backfilled loosely without tamping, then 100 per cent of the bearing strength of the pipe is developed. This method of pipe laying is deemed ordinary practice.

FIRST-CLASS METHOD OF LAYING

If the pipe is laid in a trench the bottom of which is formed to receive the lower quadrant of the pipe, and the space under and around the pipe is backfilled to a height equal to three-fourths of the diameter of the pipe (as shown in figure 3 in the table to the right) with selected granular earth material thoroughly tamped, the supporting strength of the pipe is increased 20 per cent over the ordinary method of laying previously described. This type of construction requires first-class workmanship and careful inspection.



The bell holes should be only large enough to fit the hubs of the pipe. Excessively large bell holes reduce the length of the bearing surface under the barrel of the pipe and thus permit an undesirable concentration of the load on a comparatively short length.

CAPACITY AND SIZE OF DRAIN PIPES

The amount of water to be removed by storm sewers from a given area in a given time depends upon the following factors:

1. The Area to Be Drained, in Acres (A)

This is not necessarily the total area of the site. It should be the area to be drained by a particular drain or system of drains.

2. The Run-Off Coefficient (C)

Only part of the rainfall is surface water. The remainder percolates into the soil. Surface run-off coefficients vary from .30 for average soil in unpaved areas to .90 for paved and impervious areas. The best method of determining this coefficient for a particular soil is by actual test.

3. The Maximum Rainfall in Inches per Hour (P)

The use of the ten-year, one-hour maximum rainfall curves represents conservative drainage design practice. See rainfall map on page 5.

4. The Time Allowed for Drainage, in Hours (T)

This factor will vary. Under ordinary circumstances a maximum of two or three hours should be figured.

Using these four factors:

$$\frac{A \times C \times P}{T} = R \quad \text{(Run-off in cubic feet per second)}$$

The run-off can then be translated into the required pipe size for a particular grade by using Table III.

For example: Let us suppose that we wish to compute the run-off from ten acres of an Iowa site, the soil of which has a run-off coefficient of, say, .50, and allowing three hours for the removal of the rainfall. On the rainfall map on page 5 we find that Iowa in general has a maximum precipitation of 2.25 inches per hour, based on a ten-year period. Substituting these figures into the formula just given, we have the following:

$$\frac{10 \times .50 \times 2.25}{3} = 3.75 \quad \text{cubic feet per second}$$

To translate this volume into terms of pipe size we turn to Table III, which shows the discharge in cubic feet per second for vitrified clay pipe of various sizes when laid at specified grades. Suppose, for example, that the grade of the subdrain is to be 0.9 foot per hundred feet. What size clay pipe laid at this grade will discharge 3.75 cubic feet per second? Under the column designated "0.9" in Table III we find that a 12-inch pipe discharges 3.98 cubic feet per second. We therefore use a 12-inch pipe.

From this same table we can also see that by increasing the size of pipe to 15 inches the gradient can be as small as 0.3 foot per hundred feet. Using still larger pipe reduces the necessary gradient even further.

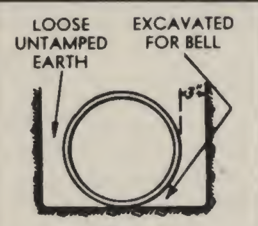
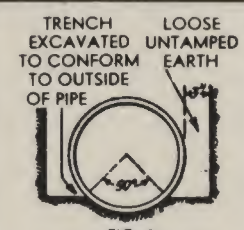
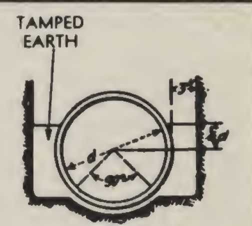
COMPUTATIONS FOR SUBSOIL DRAINAGE

For subsurface drainage the size of pipe drains required to carry ground water may be computed from Tables III and IV. Table IV shows the run-off in cubic feet per second for various areas in acres. The figures designate the portion of the rainfall which passes through the soil to the drainage pipes. For convenience the figures are given with coefficients ranging from 1/16 inch in 24 hours to 1 inch in 24 hours. The rate of run-off varies with localities and soil condition from 3/16 to ½ inch in 24 hours. ⅜ of an inch may be considered normal for computations.

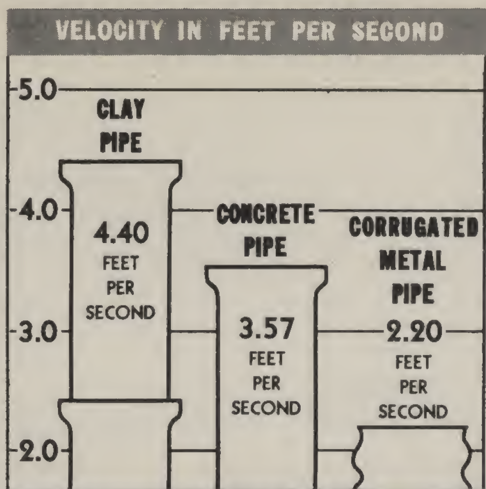
For example, should you wish to estimate the volume of water to be carried by a drain which collects from a drainage area of 100 acres, with a percolation coefficient of ⅜ of an inch in 24 hours, Table IV shows it to be 1.57 cubic feet per second. To translate this into terms of a pipe size use Table III as before.

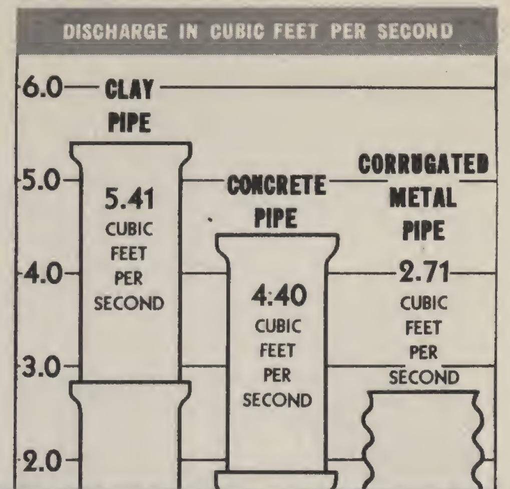
THE PHOTOGRAPHS TO THE RIGHT ARE REPRODUCED FROM "FLOW OF WATER THROUGH CULVERTS" BY DAVID L. YARNELL, FLOYD A. NAGLER AND SHERMAN M. WOODWARD, BULLETIN 1, UNIVERSITY OF IOWA STUDIES IN ENGINEERING, JUNE, 1926. COPIES OF THE ORIGINAL PHOTOGRAPHS WERE FURNISHED BY THE U. S. BUREAU OF AGRICULTURAL ENGINEERING.

TABLE II — CRUSHING STRENGTH OF CLAY PIPE BY METHOD OF LAYING

INTERNAL DIAMETER IN INCHES	EARTH BEDDING		
	 LOOSE UNTAMPED EARTH; EXCAVATED FOR BELL; FIG. 1 IMPERMISSIBLE EARTH BEDDING	 TRENCH EXCAVATED TO CONFORM TO OUTSIDE OF PIPE; LOOSE UNTAMPED EARTH; FIG. 2 ORDINARY EARTH BEDDING	 TAMPED EARTH; FIG. 3 FIRST CLASS EARTH BEDDING
	80% BEARING VALUE	100% BEARING VALUE	120% BEARING VALUE
	Minimum Crushing Strength in Pounds per Lineal Foot*		
4	1144	1430	1716
6	1144	1430	1716
8	1144	1430	1716
10	1256	1570	1884
12	1368	1710	2052
15	1568	1960	2352
18	1900	2375	2850
21	2280	2850	3420
24	2740	3425	4110
27	3160	3950	4740
30	3620	4525	5430
33	4040	5050	6060
36	4460	5575	6690

Based upon A. S. T. M. requirements by the Sand Bearing Method.





These charts show the comparative carrying capacities of three common pipes. The chart at left shows the velocity in feet per second for a 15 inch pipe laid at a slope of 0.5 foot per hundred feet. The chart to the right shows the discharge in cubic feet per second for the same pipes. These velocities and discharges are based upon Kutter's Formula, pipes flowing full. The value of "n" in each case is that given by the manufacturer of the pipe.

The internal smoothness of a pipe determines its carrying capacity. When the walls of the pipe are smooth and glassy as they are in vitrified clay sewer pipe, the flow is fast and relatively undisturbed. This is well illustrated by the photograph reproduced to the left, showing the flow through clay pipe as seen through a hole in the top of the pipe. The photograph reproduced to the right shows how corrugations break up and slow down the flow in a pipe. Although the two pipes illustrated have the same diameter, the clay pipe carries almost twice as much as the corrugated pipe.

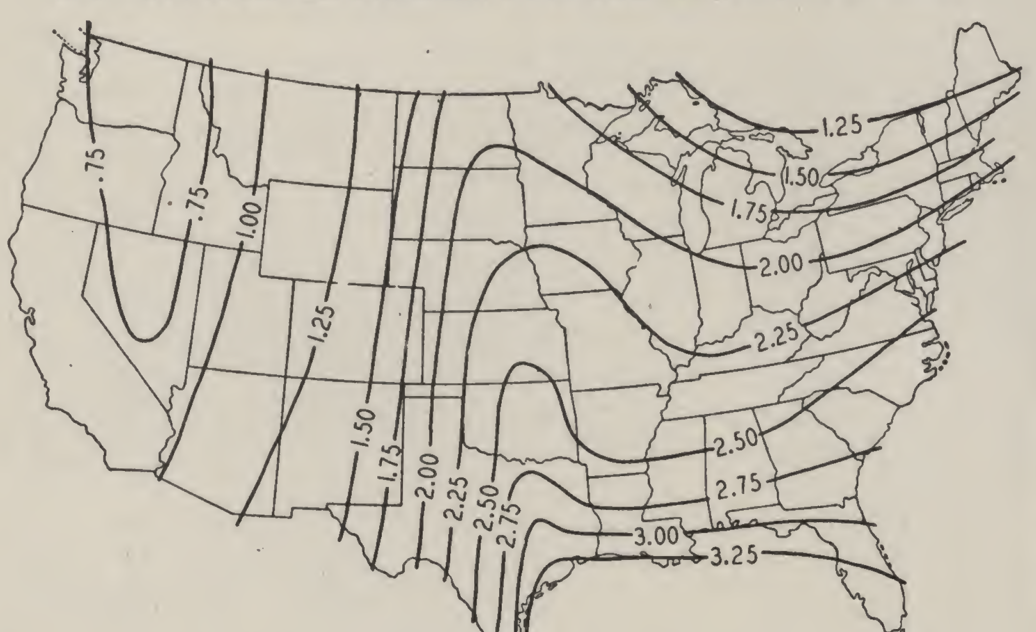
TABLE III—DISCHARGE OF CLAY PIPE IN CUBIC FEET PER SECOND FOR VARIOUS GRADES

INT. DIA. OF PIPE	SLOPE OF PIPE LINE IN FEET PER HUNDRED FEET																		INT. DIA. OF PIPE
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	
6	0.28	0.33	0.39	0.44	0.48	0.52	0.55	0.59	0.62	0.88	1.08	1.25	1.40	1.51	1.63	1.75	1.86	1.98	6
8	0.61	0.72	0.83	0.93	1.01	1.09	1.17	1.25	1.33	1.93	2.33	2.66	3.00	3.22	3.56	3.82	4.06	4.32	8
10	1.13	1.35	1.57	1.79	1.94	2.10	2.25	2.40	2.54	3.60	4.44	5.13	5.69	6.25	6.75	7.26	7.71	8.10	10
12	1.86	2.23	2.60	2.97	3.22	3.47	3.72	3.98	4.23	5.92	7.35	8.45	9.46	10.39	11.15	11.91	12.67	13.51	12
15	3.45	4.11	4.76	5.41	5.90	6.38	6.84	7.31	7.78	11.03	13.34	15.35	16.74	18.98	20.93	22.31	23.73	25.10	15
18	5.68	6.77	7.87	8.95	9.72	10.48	11.23	12.01	12.77	18.09	22.30	25.52	28.64	31.35	33.76	36.18	38.27	40.56	18
21	8.61	10.34	12.08	13.80	14.91	16.01	17.11	18.23	19.34	27.69	33.86	38.88	44.16	47.82	51.54	55.35	58.60	61.84	21
24	12.29	14.75	17.21	19.64	21.22	22.79	24.35	25.92	27.46	39.19	47.82	54.86	62.71	68.19	73.71	78.81	83.58	87.90	24
27	17.04	20.35	23.66	26.97	29.20	31.44	33.64	35.91	38.14	54.22	66.47	76.68	86.93	94.07	101.26	108.40	112.55	121.17	27
30	22.56	26.99	31.43	35.86	38.86	41.87	44.83	47.88	50.88	71.43	88.17	100.34	112.61	124.77	134.43	143.44	152.46	160.73	30
33	29.20	34.92	40.64	46.32	50.25	54.18	58.12	61.99	65.86	93.64	114.27	131.61	146.81	161.06	173.75	185.62	197.42	207.97	33
36	36.74	43.98	51.11	58.31	63.27	68.24	73.07	78.03	82.92	116.75	143.49	165.48	184.64	202.79	220.03	234.15	248.26	261.17	36

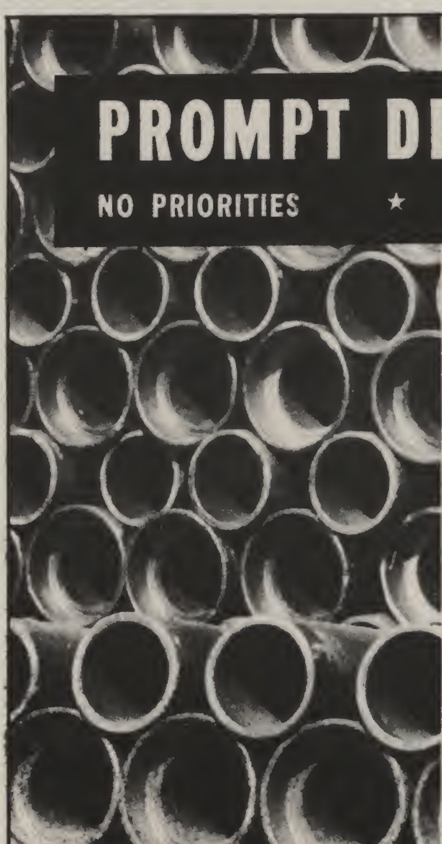
TABLE IV—RUN-OFF IN CUBIC FEET PER SECOND FOR VARIOUS ACREAGES

AREA IN ACRES	RAINFALL PERCOLATING INTO SOIL, IN INCHES, PER 24 HOURS																AREA IN ACRES
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	
10	0.03	0.05	0.08	0.11	0.13	0.16	0.18	0.21	0.24	0.26	0.29	0.32	0.34	0.37	0.39	0.42	10
20	0.05	0.11	0.16	0.21	0.27	0.32	0.37	0.42	0.48	0.53	0.58	0.64	0.69	0.74	0.80	0.85	20
30	0.08	0.16	0.24	0.32	0.40	0.47	0.55	0.63	0.71	0.79	0.87	0.95	1.03	1.11	1.19	1.26	30
40	0.11	0.21	0.32	0.42	0.53	0.63	0.74	0.84	0.95	1.05	1.16	1.26	1.36	1.47	1.58	1.68	40
50	0.13	0.26	0.39	0.52	0.66	0.79	0.92	1.05	1.18	1.31	1.44	1.57	1.70	1.83	1.97	2.10	50
60	0.16	0.32	0.47	0.63	0.79	0.95	1.11	1.26	1.42	1.58	1.74	1.90	2.05	2.21	2.37	2.53	60
70	0.18	0.37	0.55	0.74	0.92	1.10	1.29	1.47	1.66	1.84	2.02	2.21	2.39	2.58	2.76	2.94	70
80	0.21	0.42	0.63	0.84	1.05	1.26	1.47	1.68	1.89	2.10	2.31	2.52	2.73	2.94	3.15	3.36	80
90	0.24	0.47	0.71	0.94	1.18	1.42	1.65	1.89	2.12	2.36	2.60	2.83	3.07	3.30	3.54	3.78	90
100	0.26	0.52	0.79	1.05	1.31	1.57	1.83	2.10	2.36	2.62	2.88	3.14	3.41	3.67	3.93	4.19	100
150	0.39	0.79	1.18	1.57	1.97	2.36	2.75	3.14	3.54	3.93	4.32	4.72	5.11	5.50	5.90	6.29	150
200	0.53	1.06	1.59	2.12	2.65	3.18	3.71	4.24	4.77	5.30	5.83	6.36	6.89	7.42	7.95	8.48	200
250	0.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60	7.26	7.92	8.58	9.24	9.90	10.56	250
300	0.79	1.58	2.37	3.16	3.95	4.74	5.53	6.32	7.11	7.90	8.69	9.48	10.27	11.06	11.85	12.64	300
350	0.92	1.84	2.76	3.68	4.60	5.52	6.44	7.36	8.28	9.20	10.12	11.04	11.96	12.88	13.80	14.72	350
400	1.05	2.10	3.15	4.20	5.25	6.30	7.35	8.40	9.45	10.50	11.55	12.60	13.65	14.70	15.75	16.80	400
450	1.18	2.36	3.54	4.72	5.90	7.08	8.26	9.44	10.62	11.80	12.98	14.16	15.34	16.52	17.70	18.88	450
500	1.31	2.62	3.93	5.24	6.55	7.86	9.17	10.48	11.79	13.10	14.41	15.72	17.03	18.34	19.65	20.96	500
550	1.44	2.88	4.32	5.76	7.20	8.64	10.08	11.52	12.96	14.40	15.84	17.28	18.72	20.16	21.60	23.04	550
600	1.58	3.16	4.74	6.32	7.90	9.48	11.06	12.64	14.22	15.80	17.38	18.96	20.54	22.12	23.70	25.28	600
650	1.71	3.42	5.13	6.84	8.55	10.26	11.97	13.68	15.39	17.10	18.81	20.52	22.23	23.94	25.65	27.36	650
700	1.84	3.68	5.52	7.36	9.20	11.04	12.88	14.72	16.56	18.40	20.24	22.08	23.92	25.76	27.60	29.44	700
750	1.97	3.94	5.91	7.88	9.85	11.82	13.79	15.76	17.73	19.70	21.67	23.64	25.61	27.58	29.55	31.52	750
800	2.10	4.20	6.30	8.40	10.50	12.60	14.70	16.80	18.90	21.00	23.10	25.20	27.30	29.40	31.50	33.60	800
850	2.22	4.44	6.66	8.88	11.10	13.32	15.54	17.76	19.98	22.20	24.42	26.64	28.86	31.08	33.30	35.52	850
900	2.36	4.72	7.08	9.44	11.80	14.16	16.52	18.88	21.24	23.60	25.96	28.32	30.68	33.04	35.40	37.76	900
950	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00	22.50	25.00	27.50	30.00	32.50	35.00	37.50	40.00	950
1000	2.62	5.24	7.86	10.48	13.10	15.72	18.34	20.96	23.58	26.20	28.82	31.44	34.06	36.68	39.30	41.92	1000

ONE HOUR RAINFALL, IN INCHES, TO BE EXPECTED ONCE IN 10 YEARS



FROM RAINFALL INTENSITY-FREQUENCY DATA UNITED STATES DEPARTMENT OF AGRICULTURE MISCELLANEOUS PUBLICATION NO. 204.



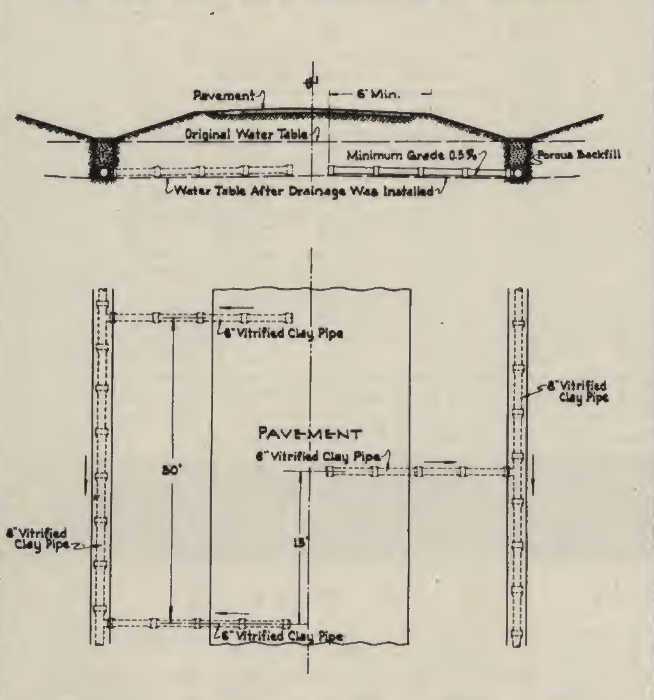
PROMPT DELIVERIES

NO PRIORITIES ★ NO COSTLY DELAYS

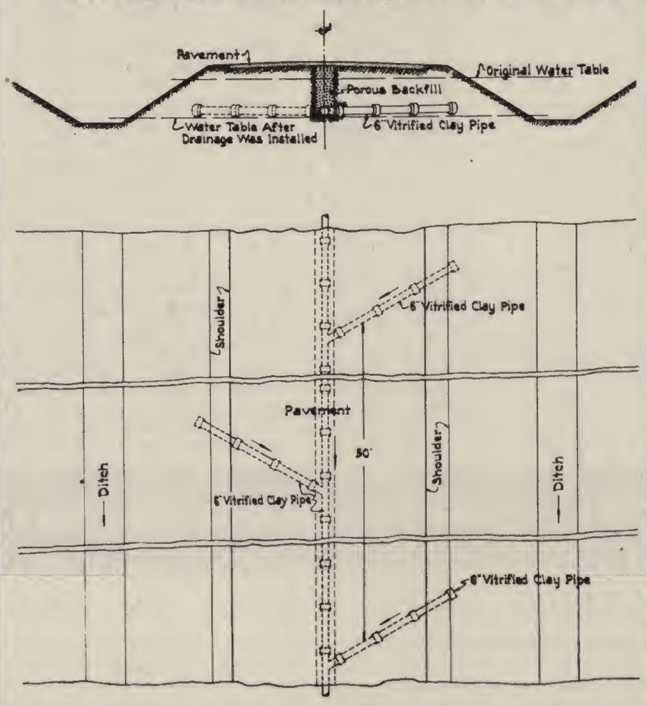
For a while last year the demand for clay pipe for war industries, housing, airport and highway drainage and other essential war work was even greater than the delivery capacity of the industry. We are sorry to say, we had to keep some of our good friends waiting. But that is all over now. Uncle Sam has been served and large stocks of clay pipe and fittings of all sizes are available for immediate delivery. Thanks for waiting.

TYPICAL CLAY PIPE SUBDRAIN INSTALLATIONS FOR HIGHWAYS

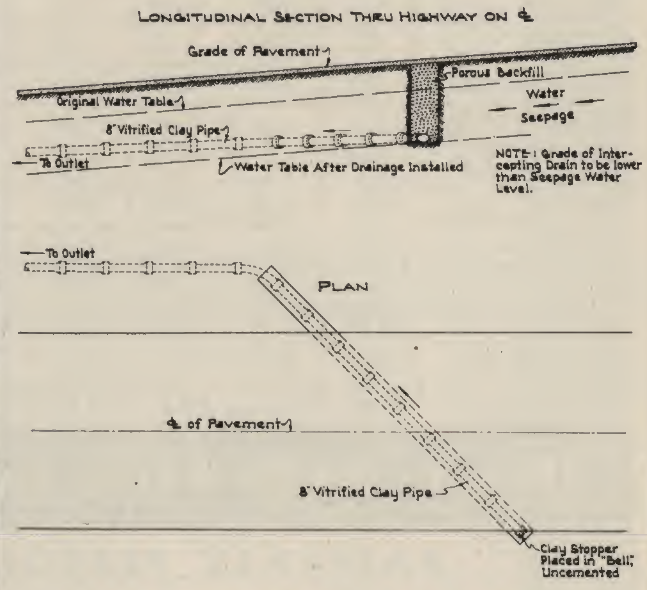
1. DOUBLE MAIN INSTALLATION WITH LATERALS



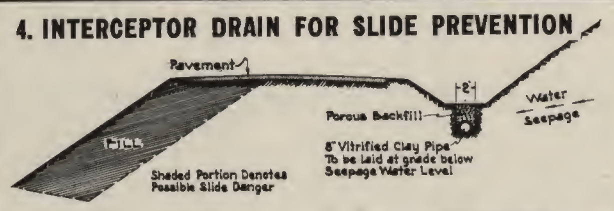
2. SINGLE MAIN INSTALLATION WITH LATERALS



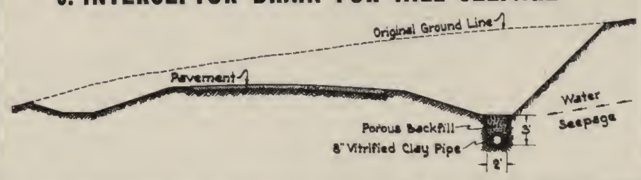
3. INTERCEPTOR DRAINS FOR LONGITUDINAL ROADWAY SEEPAGE



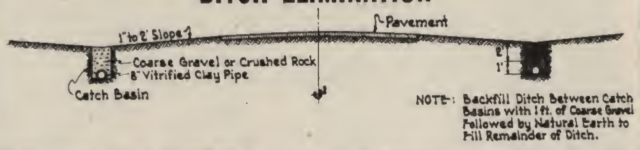
4. INTERCEPTOR DRAIN FOR SLIDE PREVENTION



5. INTERCEPTOR DRAIN FOR HILL SEEPAGE



6. SIDE DRAINS FOR HIGHWAY WIDENING AND DITCH ELIMINATION



Frost heave, soft shoulders, eroded gullies, dips in the surface, shifting of the road from true alignment, deep side ditches and costly perpetual maintenance have been eliminated in modern highway construction by the new science of highway drainage and a better knowledge of soils and their behaviors when wet. Unable to shelter the highway from rain, snow, sleet and other elements, the highway engineer has solved the problem of protection with an ingenious system of underdrains that guard the subgrade from all angles, and which quickly dispose of surface waters that make highways slippery and dangerous.

The installations shown here are called "typical," but as every engineer knows, local conditions determine the final plan. The basic idea is to keep the subgrade dry . . . to lower the water table where present to the point where it can do no harm . . . to intercept water seeping toward the subgrade.

Installations 1 and 2 above are primarily designed to lower the water table. They accomplish this with a system of clay pipe drains installed in trenches wholly or partially backfilled with a porous material such as gravel or crushed rock. Both mains and laterals are usually laid with open joints as described on page 3. Under some conditions, however, only the lateral lines are left with open joints.

Where one system of drains does both surface and subsoil drainage, the trench is completely backfilled with porous material and the pipe is laid with open joints. In major highway construction regular grated inlets are sometimes used.

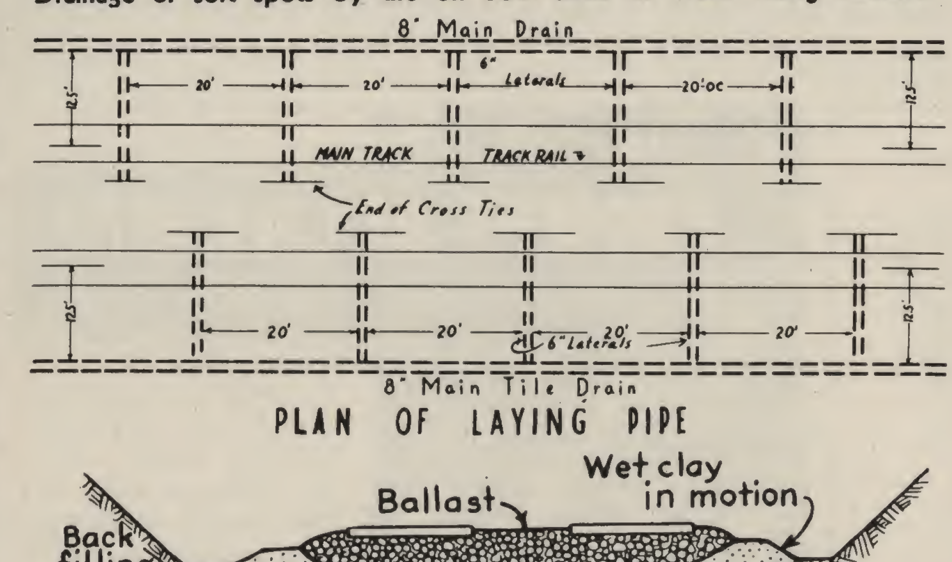
Highway engineers frequently have trouble with seepage and wet spots in cuts. This is usually caused by water flowing over dense inclined layers in the soil. The cut bares these layers and the water literally flows out. To stop this trouble, interceptor drains are laid slightly below the strata over which the water is moving and at right angles to the movement of the water. The flowing water strikes the coarse backfill, percolates to the pipe, enters the open joints and is carried away before it reaches the subgrade. Installations 3, 4 and 5 are of this type.

Installation 6 is designed to eliminate unsightly and dangerous ditches. Common practice is to lay clay drains of adequate size on both sides of the roadway. The pipe is laid with open joints, and is backfilled with a porous material to a depth of about one foot. The remainder of the backfill is natural earth. At intervals of 150 to 200 feet the coarse backfill is carried to the surface to act as a catchbasin. In some places where the run-off from the surfacing is apt to be especially heavy regular grated inlets are used.

TYPICAL CLAY PIPE SUBDRAIN INSTALLATION FOR RAILWAYS

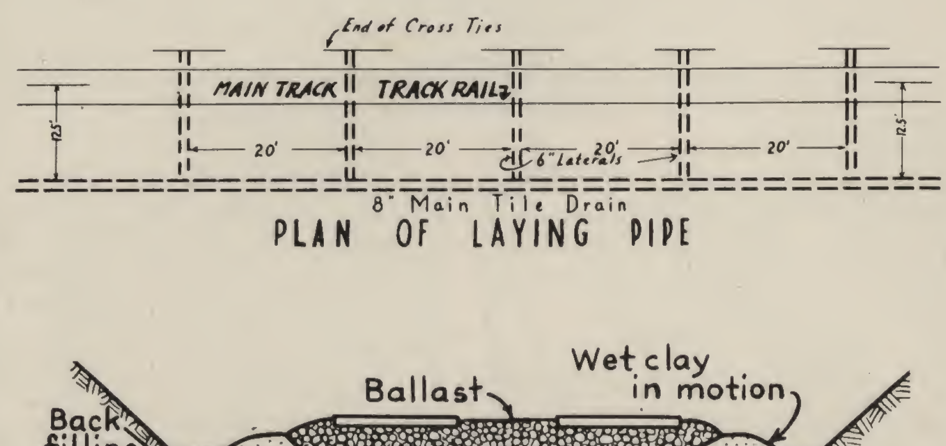
DOUBLE MAIN DRAINAGE

Drainage of soft spots by tile on both sides of Track Using Laterals.



SINGLE MAIN DRAINAGE

Drainage of Soft Spots on One Side of Track Using Laterals.

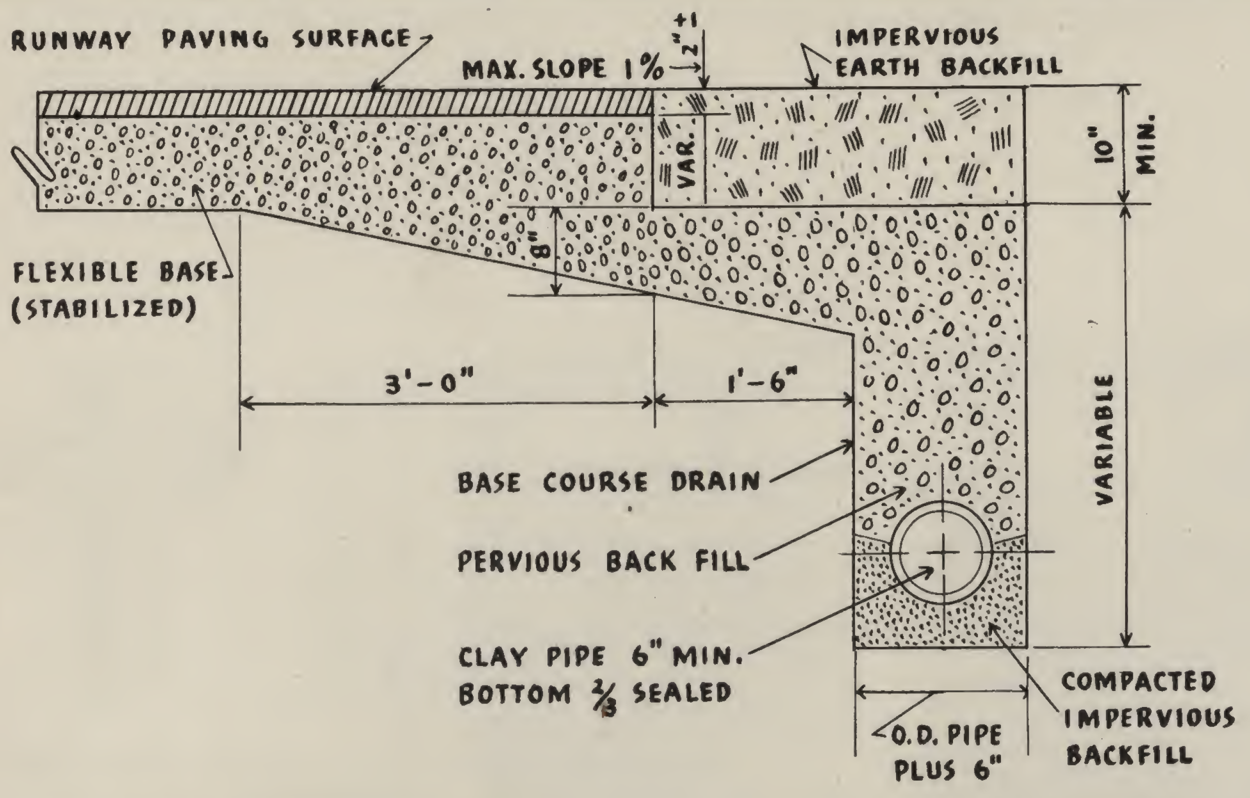


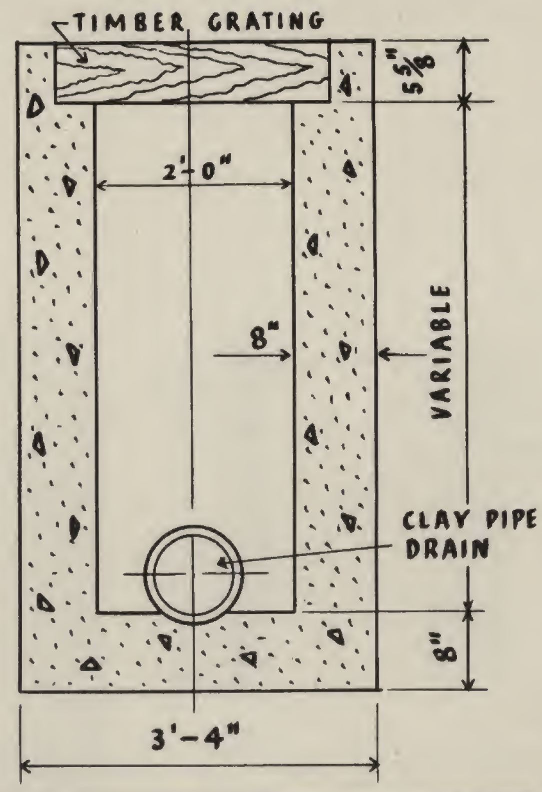
The inauguration of present-day, high-speed trains together with extra heavy freight locomotives and long, heavy trains put a burden upon roadbeds entirely unknown a few years ago. Probably the hardest thing a maintenance department has to contend with to keep tracks fit for fast heavy trains is wet roadbed. Water gets under tracks in many ways, but there is only one successful way to remove it; it must be drained off through a system of permanent subdrains, preferably of clay pipe.

In general, railway drainage is the same as highway drainage. Main drainage lines are laid on one or both sides of the tracks with laterals extending under the roadbed to catch and carry away subsurface water. In cuts, interceptor drains such as shown in highway installations Nos. 4 and 5 are very effective.

Clay pipe drains are ideal for railway drainage because of their availability and corrosion resistance. They are the only type of subdrain that can be backfilled with engine cinders without harm. The short lengths are easy to handle in narrow trenches under the rails and provide more openings for the water to enter.

TYPICAL CLAY PIPE SUBDRAIN INSTALLATIONS FOR AIRPORTS





Like other types of subdrainage, airport installations are designed to stabilize the subgrade and subbase. "The greatest danger of an inadequate drainage system on an airport is, perhaps, the *resulting softening* of subgrade and subbase due to frequent or sustained overflow and the *hazard to traffic* which may be using the airport at such periods of overflow."

"Subsurface drainage to be considered on airports consists in general of providing intercepting lines, draining wet masses or areas, controlling moisture in base or subbase or any combination of these."

"An intercepting drain is usually placed parallel to and at edge of a runway in such a way as to prevent the ground water from reaching the critical area under the runway surface. This drain should be placed across and at the lowest portion of the seepage strata in order to cut off and divert the entire flow."

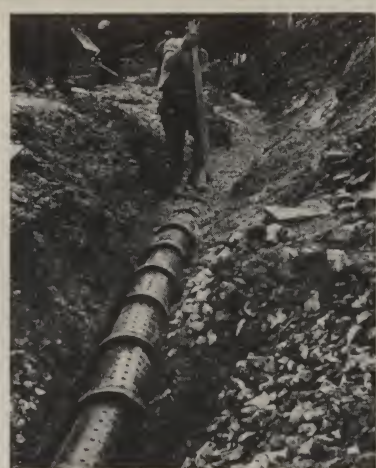
"To preclude the possibility of large quantities of water entering such drains, it is considered desirable not to extend the pervious backfill surrounding such drains to the surface, but to provide a relatively impervious covering. It is evident that the only moisture which might damage the pavement is that which enters the subbase or base, and in order to provide economical subdrain sizes, this infiltration should be reduced as much as possible. The surface run-off should be handled in a separate system where topography permits."[1]

1 Airport Drainage Design Information, Department of Commerce, Airport Division, August 1, 1942.

CLAY PIPE SUBDRAIN INSTALLATIONS IN PHOTOGRAPHS

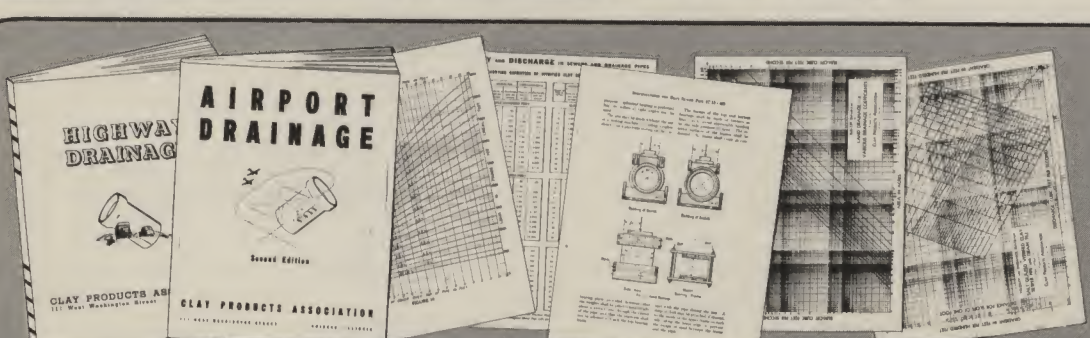
These photographs show clay pipe interceptor drains being installed to protect a new highway from hill seepage. Above, the drain is being installed in the ditch beside the roadway. Below, the drain is laid high on the hillside.

The photograph above shows a typical clay pipe subdrain installation. The pipe is laid with open joints in a trench backfilled with coarse material. To prevent the pipe from clogging during initial "wash-downs," pieces of roofing material are placed over the openings. After the drain has been in use for a time, there is little chance of clogging.



The two photographs above show perforated bell and spigot clay pipe being used to drain wet spots on one of America's crack highways.

Large clay pipe mains being laid as part of a complete surface and subsurface drainage system under a new superhighway.



FOR COMPLETE DATA ON SUBDRAINAGE

The information given on these pages is sketchy because of the limited space available. Complete data and technical information will be cheerfully supplied to all engineers, contractors, architects, farmers, building supply dealers and others interested in subsoil drainage. Just drop a note or card to this Association telling us what your problem is. We will answer, promptly, specific questions and send you detailed literature.

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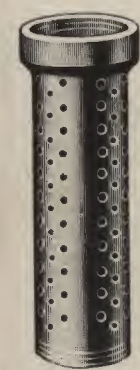
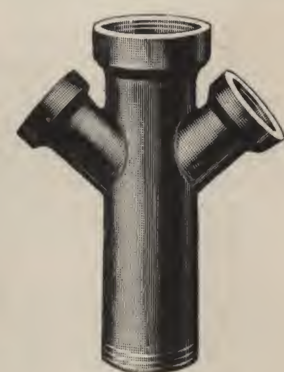
Clay Pipe and Fittings are available in a wide variety of shapes and sizes.

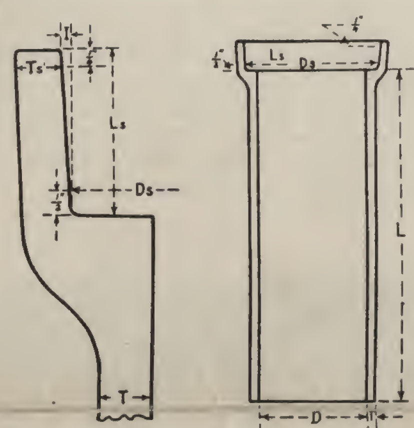
THE PERFECT SUBSOIL DRAIN

No other drainage pipe can offer the advantages of vitrified clay pipe. It is absolutely rust and corrosion resistant. It has a high carrying capacity. It is easily obtained. Its cost is low. It is not affected by priorities. Its short lengths are easy to handle in narrow trenches and tunnels. The bell and spigot design gives better, more complete drainage, without clogging. It comes in all the sizes and shapes needed for subdrainage.





Left: Perforated clay pipe available in sizes up to 12 inches in diameter.

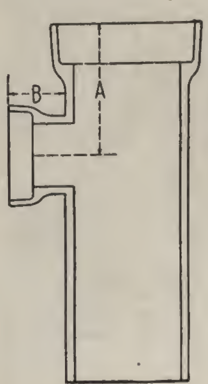


★ DIMENSIONS OF CLAY SEWER PIPE* ★

Internal Diameter (D), in.	Laying Length (L), ft.	Annular Space, in.	Depth of Socket (Ls), in.	Thickness of Barrel (T), in.
4	2	3/8	1¾	½
6	2, 2½	½	2¼	5/8
8	2, 2½, 3	½	2½	¾
10	2, 2½, 3	½	2½	7/8
12	2, 2½, 3	9/16	2¾	1
15	2, 2½, 3	5/8	2¾	1¼
18	2, 2½, 3	5/8	3	1½
21	2, 2½, 3	11/16	3¼	1¾
24	2, 2½, 3	11/16	3 3/8	2
27	2½, 3	13/16	3½	2¼
30	2½, 3	13/16	3½	2½
33	2½, 3	7/8	4	2 5/8
36	2½, 3	7/8	4	2¾

*Applications of dimensions given in this table are shown on drawing to the left.

Vitrified Clay Culvert Pipe is available for immediate delivery.

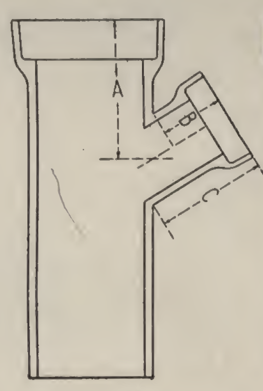


T Branches are available in a wide variety of sizes. See table to right for dimensions.

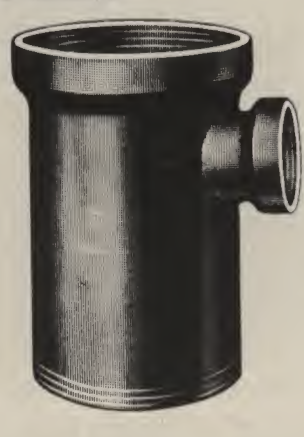
★ APPROXIMATE DIMENSIONS OF "Y" AND "T" BRANCHES ★

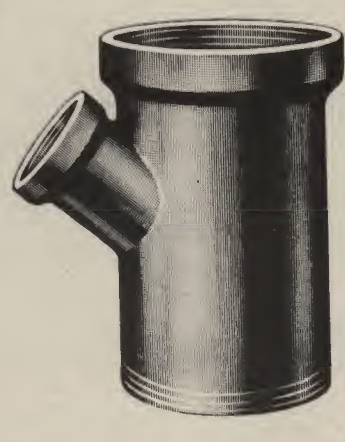
Barrel Diameter Inches	Spur Diameter Inches	"T" BRANCHES A Inches	"T" BRANCHES B Inches	"Y" BRANCHES A Inches	"Y" BRANCHES B Inches	"Y" BRANCHES C Inches
4	4	6	3½	8½	3¾	8½
6	4	7	3½	9	3¾	8½
6	6	8	4½	10	4½	11½
8	4	7½	3½	9	3¾	8½
8	6	8½	4½	11	4½	11½
8	8	9½	5	12	4½	12½
10	4	8½	3½	10	3¾	8½
10	6	10	4½	12	4½	11½
10	8	11	5	13	5	13
10	10	11½	5	14	6	14¾
12	4	9	3½	10	3¾	8½
12	6	10	4½	11	4½	11
12	8	11	5	13	5½	13
12	10	11½	5	14	6	13
12	12	12½	5	16	6½	17½
15	6	9½	4	12	4	10¼
15	8	11	5	14	4½	12½
15	10	11½	5	16	5	14¾
15	12	12½	5	17	5½	17½
15	15	14	5½			
18	6	11	4½	13	4	10¼
18	8	11½	4½	15	4½	12½
18	10	12½	4½	17	5	14¾
18	12	15	5	18	5½	17½
18	15	16	5½			
18	18	17	6			
21	6	10½	4	14	4	10¼
21	8	11½	4½	15	4½	12½
21	10	13½	4½	17	5	14¾
21	12	14	5	19	5½	17½
21	15	15½	5	19½	6	20¾
21	18	17	6			
21	21	18	6½			
24	6	12	4	14	4	10¼
24	8	13	4½	16	4½	12½
24	10	14	4½	18	5	14¾
24	12	14½	5	19	5	17½
24	15	15½	5	19½	6	20¾
24	18	17	6			
24	21	18	6½			
24	24	19	6½			
27	6	12	4½	16	4½	11½
27	8	13½	4½	17	4½	12½
27	10	14	4½	18	5	12¾
27	12	15½	5	19	5½	17½
27	15	17	5	21	6	20¾
27	18	17	6			
30	6	13	4½	16	4½	11½
30	8	14	4½	17	4½	12½
30	10	15	5	18	6½	13
30	12	16	6	19	6½	16½
30	15	17	6	21	7	20¾
30	18	18	6			
33	6	13	4½	17	4½	11½
33	8	14	5	18	6	13
33	10	15	5	19	6½	13
33	12	16	6	20	6½	16½
33	15	17	6	22	7	17
33	18	18	8			
36	6	13	4½	17	4½	11½
36	8	14	5	18	4½	13
36	10	15	5	19	5	15½
36	12	16	5	19	5½	17½
36	15	17	5	21	6	20¾
36	18	18	6			

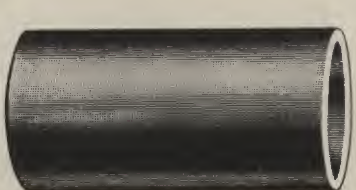
NOTE—Dimensions A, B and C are approximate.



Y Branches are available in a wide variety of sizes. See table to left for dimensions.







Vitrified clay drain tile is available in sizes up to 36 inches in diameter.

Split or Channel Pipe is handy for use as surface collection drains.

SCP 170-8M-1-43

Southern Clay Pipe
First National Bank Bldg.
Atlanta, Georgia

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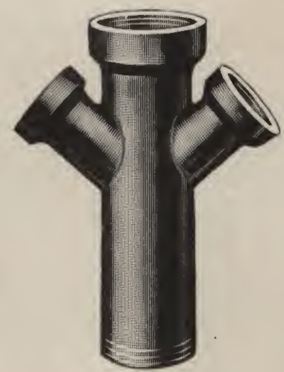
VOL. 9 NO. 1

Mr. Guy J. Seghers
508 Baronne Bldg.
New Orleans, La.

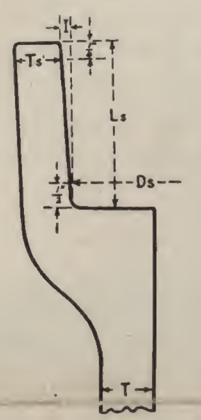
Clay Pipe and Fittings are av[...] able in a wide variety of sha[...] and sizes.

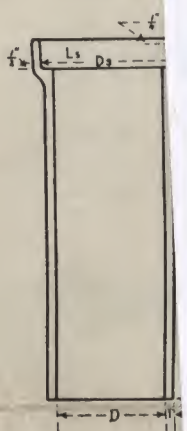
THE PERFECT SUBSOIL DRAIN

No other drainage pipe can offer the advantages of vitrified clay pipe. It is absolutely rust and corrosion resistant. It has a high carrying capacity. It is easily obtained. its cost is low. It is not affected by priorities. Its short lengths are easy to handle in narrow trenches and tunnels. The bell and spigot design

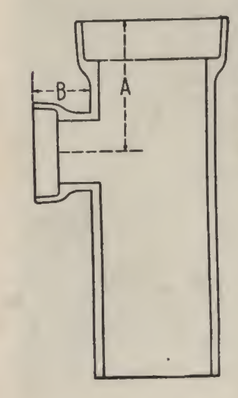


[...]ft: Perforated clay pipe avail[...]le in sizes up to 12 inches in [...]meter.

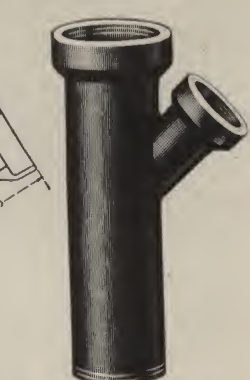




[...]fied Clay Culvert Pipe is avail[...] for immediate delivery.



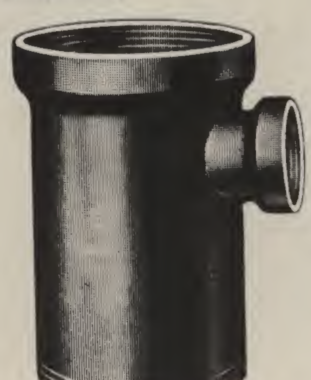
T Branches are available in a wide variety of sizes. See table to right for dimensions.

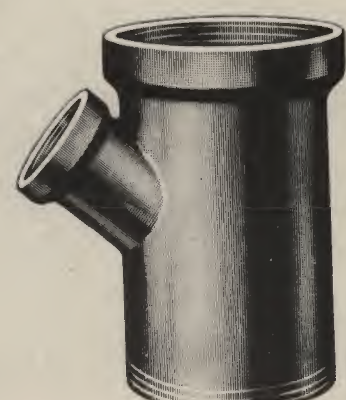


[...]nches are available in a wide variety of sizes. See table to left for dimensions.

					5	14¾
[illegible]	12	12½	5	17	5½	17½
15	15	14	5½			
18	6	11	4½	13	4	10¼
18	8	11½	4½	15	4½	12½
18	10	12½	4½	17	5	14¾
18	12	15	5	18	5½	17½
18	15	16	5½			
18	18	17	6			
21	6	10½	4	14	4	10¼
21	8	11½	4½	15	4½	12½
21	10	13½	4½	17	5	14¾
21	12	14	5	19	5½	17½
21	15	15½	5	19½	6	20¾
21	18	17	6			
21	21	18	6½			
24	6	12	4	14	4	10¼
24	8	13	4½	16	4½	12½
24	10	14	4½	18	5	14¾
24	12	14½	5	19	5	17½
24	15	15½	5	19½	6	20¾
24	18	17	6			
24	21	18	6½			
24	24	19	6½			
27	6	12	4½	16	4½	11½
27	8	13½	4½	17	4½	12½
27	10	14	4½	18	5	12¾
27	12	15½	5	19	5½	17½
27	15	17	5	21	6	20¾
27	18	17	6			
30	6	13	4½	16	4½	11½
30	8	14	4½	17	4½	12½
30	10	15	5	18	6½	13
30	12	16	6	19	6½	16½
30	15	17	6	21	7	20¾
30	18	18	6			
33	6	13	4½	17	4½	11½
33	8	14	5	18	6	13
33	10	15	5	19	6½	13
33	12	16	6	20	6½	16½
33	15	17	6	22	7	17
33	18	18	8			
36	6	13	4½	17	4½	11½
36	8	14	5	18	4½	13
36	10	15	5	19	5	15½
36	12	16	5	19	5½	17½
36	15	17	5	21	6	20¾
36	18	18	6			

NOTE—Dimensions A, B and C are approximate.





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